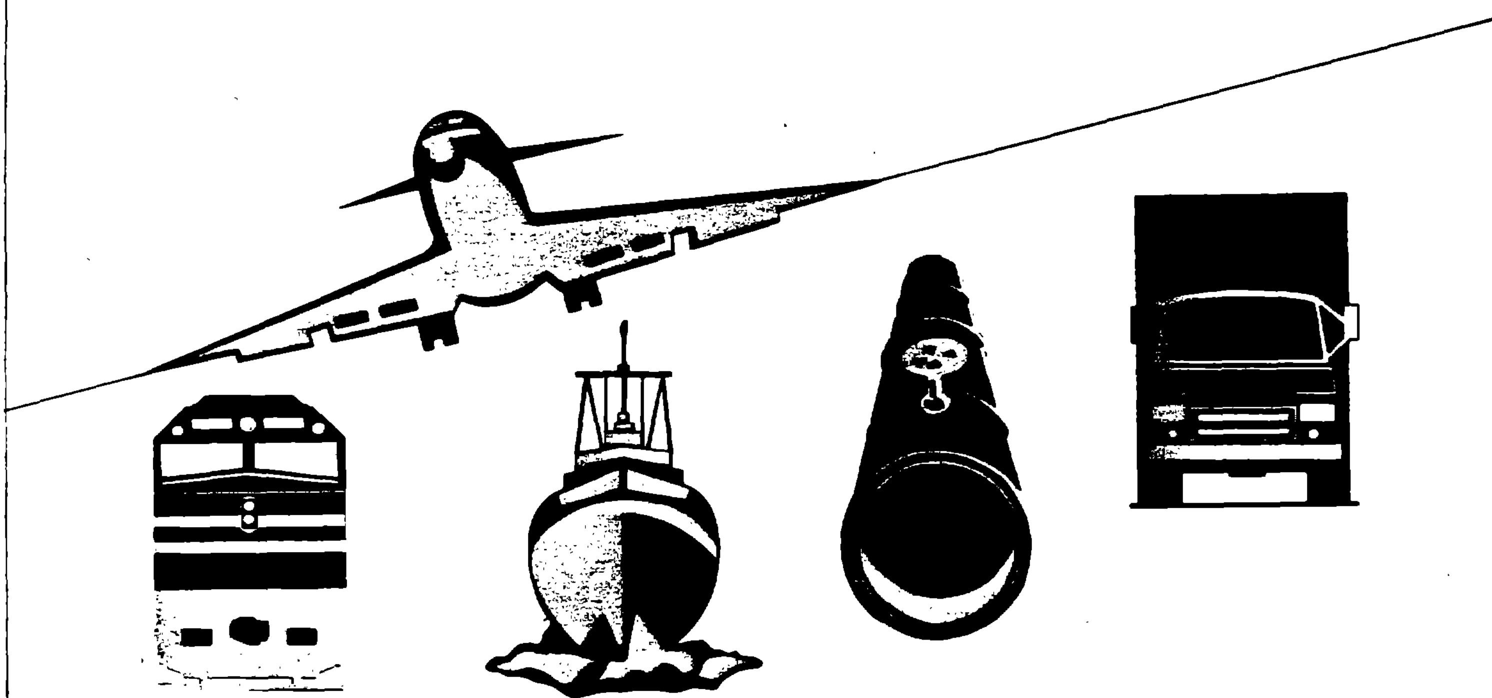
PB98-916612
NTSB/REC-98/12

PB98-916612

# NATIONAL TRANSPORTATION SAFETY BOARD

## TRANSPORTATION SAFETY RECOMMENDATIONS

### ADOPTED DURING THE MONTH OF DECEMBER, 1998



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16. Abstract


This publication contains safety recommendations in aviation and railroad modes of transportation adopted by the National Transportation Safety Board during the month of December, 1998.

AVIATION

A-98-125 and 126
A-98-127 through 128

RAILROAD

R-98-69
R-98-70
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# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

**Date:** December 3, 1998

**In reply refer to:** A-98-125 and -126

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On December 6, 1995, Pakistan International Airlines (PIA) flight 722, a Boeing 747-240 "Combi" airplane,[1] experienced an uncontained failure[2] in the low pressure turbine (LPT) area of the No. 2 engine, a General Electric Aircraft Engines (GE) CF6-50E2, shortly after takeoff from John F. Kennedy International Airport (JFK), New York.[3] The flightcrew reported that as the airplane was climbing through 1,000 feet, they heard a loud thud and grinding noise and that the airplane then yawed to the left. The flight engineer reported that immediately after he heard the thud, he noted that the No. 2 engine oil pressure and oil quantity gauges were both indicating zero. The flightcrew continued the climb and later shut down the No. 2 engine. The airplane returned to JFK and landed without further incident. None of the 240 passengers and 15 crewmembers on board were injured. The airplane was operating on an instrument flight rules (IFR) flight plan under the provisions of Title 14 Code of Federal Regulations (CFR) Part 129 as a regularly scheduled international passenger and cargo flight from JFK to Charles de Gaulle Airport, Paris, France.

The examination of the No. 2 engine revealed that most of the LPT module was missing (see figure 1). The airplane had punctures to its left wing leading edge slats and to a landing gear door. In addition, the No. 1 engine had hard body impact damage[4] to 18 of the 38 fan blades, and the fan cowl had impact damage from the debris ejected from the No. 2 engine.

[1] A Boeing 747 Combi airplane is configured such that it can carry both passengers and cargo on the main deck.
[2] An uncontained engine failure occurs when an internal part of the engine fails and is ejected, or results in other parts being ejected, through the cowling.
[3] For more detailed information, see Brief of Incident NYC96IA036 (enclosed).
[4] Hard body impact damage is characterized by a serrated appearance and deep cuts to the airfoil's leading and trailing edges. Hard body impact damage can result from impact with metal parts, concrete, asphalt, and rocks.

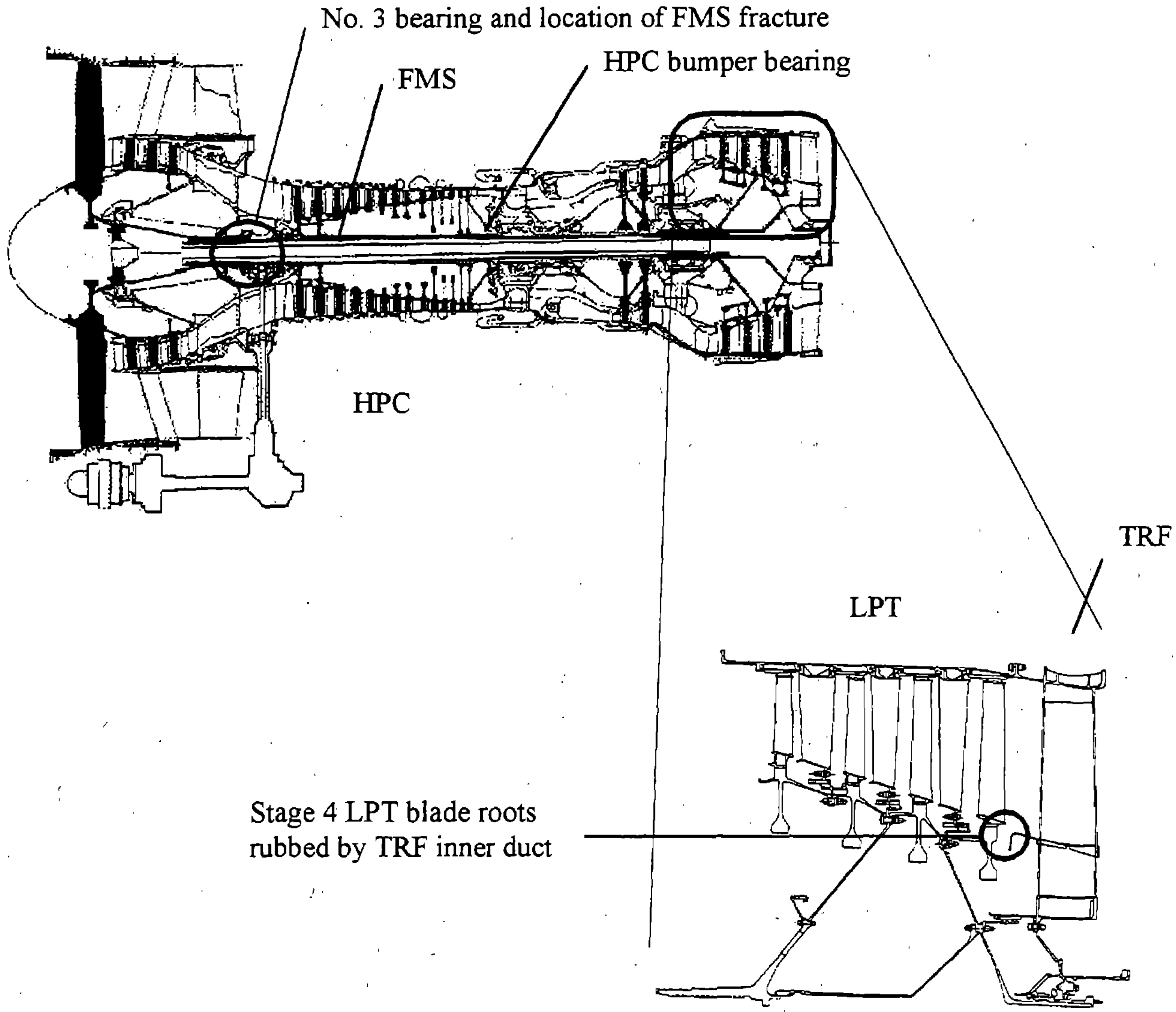


Figure 1. Cross section of CF6-50 engine and expanded view of LPT module

Disassembly of the engine, serial number (SN) 455-954, at GE's Engine Maintenance Center, Ontario, California, under the direction of the National Transportation Safety Board, revealed that the fan midshaft (FMS) was fractured circumferentially, just aft of the No. 3 (roller) bearing. Although the No. 3 bearing was damaged, the damage was typical of secondary damage that would have occurred late in the engine failure sequence.

Examination of the fractured FMS by the Safety Board's and GE's materials laboratories revealed a fatigue fracture with multiple origins on the outer diameter (OD) of the shaft that propagated inward. The examinations also revealed a color variation across the fracture surface and a reduction of the material hardness at the fracture in comparison to the other areas of the FMS and the engineering drawing specification, indicating that the part had been previously overheated. In addition, SerMetel paint[5] was found on the surface of the fatigue fracture, suggesting that the crack existed but was not detected when the shaft had been painted following a previous repair.

The maintenance records for the fractured FMS, part number 9032M21P18, SN MPOE3573, show that it had been installed in another PIA CF6-50 engine, SN 455-927, which was brought into PIA's engine shop on September 26, 1986, because of a No. 3 bearing failure. The records show that the FMS was overhauled, magnetic particle inspected (MPI),[6] hardness checked in Area B,[7] dimensionally inspected, and painted. At the time of the No. 3 bearing failure in PIA engine SN 455-927, the FMS had 4,594 cycles since new (CSN). The fracture occurred 9,235 cycles later at 13,829 CSN. The records also show that PIA overhauled, conducted an MPI, and painted the FMS on August 12, 1991, at 9,764 CSN, 4,065 cycles before the fracture; and on December 14, 1993, at 12,292 CSN, 1,537 cycles before the fracture. There was no record that the FMS had been inspected by etching the surface,[8] as required by the CF6-50 Shop Manual[9] if the shaft had been rubbed.[10]

The Safety Board is concerned about the potential for other FMS fractures from rubs sufficient to overheat the material and reduce its tensile and fatigue properties but not sufficient to cause damage warranting an inspection of the shafts. However, the Safety Board notes that as a result of the PIA investigation, GE issued Alert Service Bulletin CF6-50 72-A1120 on April 4, 1997, which identifies other CF6-50 FMSs that had been rubbed and provides a one-time eddy current inspection procedure to identify and remove from service any FMSs that were overheated.

The disassembly of the PIA engine showed that the center section of the FMS had become wedged into the high pressure compressor (HPC) bumper bearings. The design of the CF6-50 engine's FMS is such that the OD of the forward half of the shaft is greater than the inner diameter of the bumper bearing on the inside of the HPC rear hub. On the PIA engine, when the FMS fractured at its forward end, the rear section moved aft, and the larger diameter section of the shaft became wedged into the bumper bearing, limiting the rearward movement of the LPT

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[5] SerMetel paint is an aluminum-based corrosion preventative coating.

[6] MPI is a nondestructive method of detecting cracks and other defects in ferromagnetic materials such as iron or steel. The inspection consists of magnetizing the part with high-amperage, direct current electricity, thus creating magnetic lines of flux, then applying or immersing the part in a liquid containing ferromagnetic particles in suspension. The ferromagnetic particles align themselves with the magnetic lines of flux on the surface of the part forming a pattern. If a discontinuity is present in the material on or near the surface, opposing magnetic poles form on either side of the discontinuity and the pattern is disrupted, forming an "indication." The indications assume the approximate size and shape of the surface projection of the discontinuity; however, indications are more visible when the defects are approximately perpendicular to the magnetic lines of flux.

[7] Area B is on the forward section of the FMS, away from the area of the fracture.

[8] Etching the surface is a nondestructive test procedure that will show if the base metal has been locally overheated because of a rub.

[9] GE CF6-50 Task Numbered Shop Manual, Inspection, Subtask 72-24-01-220-053.

[10] The No. 3 bearing supports and aligns the forward end of the FMS. When the bearing fails, the FMS shifts slightly, allowing contact with the HPC disk bore causing rubbing and frictional overheating. In the PIA event, the rub on the FMS would have been evident when it was repaired in 1986 after the No. 3 bearing failure. Since the FMS was painted in 1986, after the No. 3 bearing failure, the rub damage would not have been evident during subsequent inspections.

rotor. With the FMS wedged into the bumper bearing, the LPT rotor was then driven by the high pressure rotor, which has a rotational speed more than twice the rpm limit of the low pressure rotor. Additionally, two stage 4 LPT blade roots recovered from the core cowl had circumferential grooves on their rear faces. The grooves corresponded to the forward edge of the turbine rear frame (TRF) inner duct, indicating that additional structure had limited the rearward movement of the LPT rotor and meshing[11] action, thus permitting the rotor to overspeed. Several stage 1 LPT blades recovered from the wing slat area were rubbed on the rear faces of their roots and had the rear portions of the blade root serrations sheared consistent with the radial outward movement of the blades, suggesting that those blades were pushed out of the disk from the rear and separated under high-centrifugal loads.

On February 22, 1996, a Continental Airlines McDonnell Douglas DC-10 airplane sustained uncontained LPT damage to the No. 3 engine, a CF6-50C2, because of an FMS fracture during the takeoff roll at Houston, Texas. The flightcrew reported that when they heard the engine surge,[12] they immediately retarded the power levers to idle and rejected the takeoff. The engine's core cowl was penetrated by turbine blade fragments, but no damage to any other part of the airplane occurred. The examination of the Continental Airlines engine showed that the FMS had fractured near the forward end after being rubbed by the HPC air duct, which had fractured circumferentially along the seam of a previous weld repair because of porosity in the weld. The examination also revealed that the FMS had become wedged into the HPC bumper bearing, and the stage 4 LPT blades were rubbed on their rear faces, much like on the PIA engine.

GE reported that a dimensional inspection of the LPT disks showed that the disks had "grown," indicating that the LPT rotor had accelerated to 140 percent rpm.[13] The Safety Board is concerned about the LPT rotor overspeeds and uncontained LPT damage that occur even when the flightcrew promptly retards the engine power, as was done by the Continental Airlines flightcrew. The Safety Board is further concerned about the extent of resultant damage when an FMS fracture occurs and the flightcrew cannot immediately reduce power on the affected engine, such as on the PIA flight. The rubs on the rear faces of the stage 4 LPT blade roots and the wedging of the FMS into the HPC bumper bearing, which were noted on the PIA and Continental Airlines engines, indicate that the meshing action of the CF6-50 engine's LPT rotor is being impeded. The turbine disk growth that was noted on the Continental Airlines engine shows that the limited meshing action allowed the overspeed of the LPT. Therefore, the Safety Board believes that the Federal Aviation Administration (FAA) should require GE to modify the CF6-50 engine to eliminate the impediments to the aft translation of the LPT rotor that limits the amount of meshing that occurs in the event of an FMS fracture.

[11] Meshing is the desired clashing of the turbine blades and vanes following a turbine rotor shaft fracture that is intended to decelerate the rotor and to break the blades into small particles, thus reducing the likelihood of blades penetrating an engine casing.

[12] A surge is a disruption of the airflow through the compressors resulting in a stagnation or reversal of the airflow and is typified by loud reports or bangs and flames from the inlet and tailpipe.

[13] When a disk exceeds its rotational speed limit, the extreme centrifugal loads cause plastic deformation of the part so that the diametrical dimensions of the disk are greater following the overspeed event.

Because of other incidents, the Safety Board is also concerned about the LPT containment capability of GE's CF6-80 series engines. On January 24, 1996, American Airlines flight 1745, an Airbus Industrie A300-600 airplane, experienced an uncontained LPT failure in the No. 1 engine, a GE CF6-80C2A5, just after takeoff from Philadelphia, Pennsylvania. It was operating on an IFR flight plan under the provisions of 14 CFR Part 121 as a regularly scheduled passenger flight from Philadelphia to San Juan, Puerto Rico. The flightcrew reported that as the airplane was climbing through 1,000 feet, they heard a "soft thunk" and the No. 1 engine spooled down to idle. The airplane returned and landed at Philadelphia without further incident, and none of the passengers and crewmembers were injured. The flightcrew reported that the No. 1 engine ran at idle power until the crew shut it down after the airplane had landed.

Examination of the No. 1 engine revealed that the core cowl had a 15-inch long (circumferential) by 6-inch wide (axial) hole in the plane of the stage 4 LPT rotor. There were numerous dents and impact marks on the underside of the left wing's inboard aileron and the outboard side of the inboard flap track fairing, both of which are directly aft of the No. 1 engine's exhaust.[14]

The engine was disassembled and examined under the direction of the Safety Board at Motoren-und Turbinen-Union (MTU), Hannover, Germany.[15] The disassembly revealed that the tip of one interturbine temperature ($T_{4.9}$)[16] probe had broken off and impacted one stage 1 LPT blade, causing a fatigue fracture of the airfoil near the blade tip shroud (see figure 2). All of the stage 2, 3, 4, and 5 LPT blades were found in their respective disks; however, all were fractured transversely across the airfoils at various lengths above the blade root platforms. The disassembly also revealed that the LPT case had a 17-inch by 2-inch wide hole in the stage 4 LPT plane of rotation. The damage to the LPT rotor was progressively worse along the gaspath, suggesting that the stage 1 LPT blade tip separated first, that all of the blades in the following stages were then fractured, and that the mass of material became larger as it progressed through the rotor, subsequently resulting in a case rupture in the stage 4 area.

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[14] There was no indication that any of the material that exited through the core cowl struck the wing or fuselage.

[15] American Airlines had the maintenance and repair of its GE CF6-80C2 engines contracted out to MTU at that time.

[16] Gas turbine engine convention is to number the aerodynamic engine stations with station 1 being at the engine inlet and to use progressively higher numbers along the gas path to the exhaust nozzle. Generally, the number is accompanied by a prefix P (pressure) or T (temperature). In the CF6-80 series engine, station 4.9 would indicate that the probe was located between the high and low pressure turbine rotors.

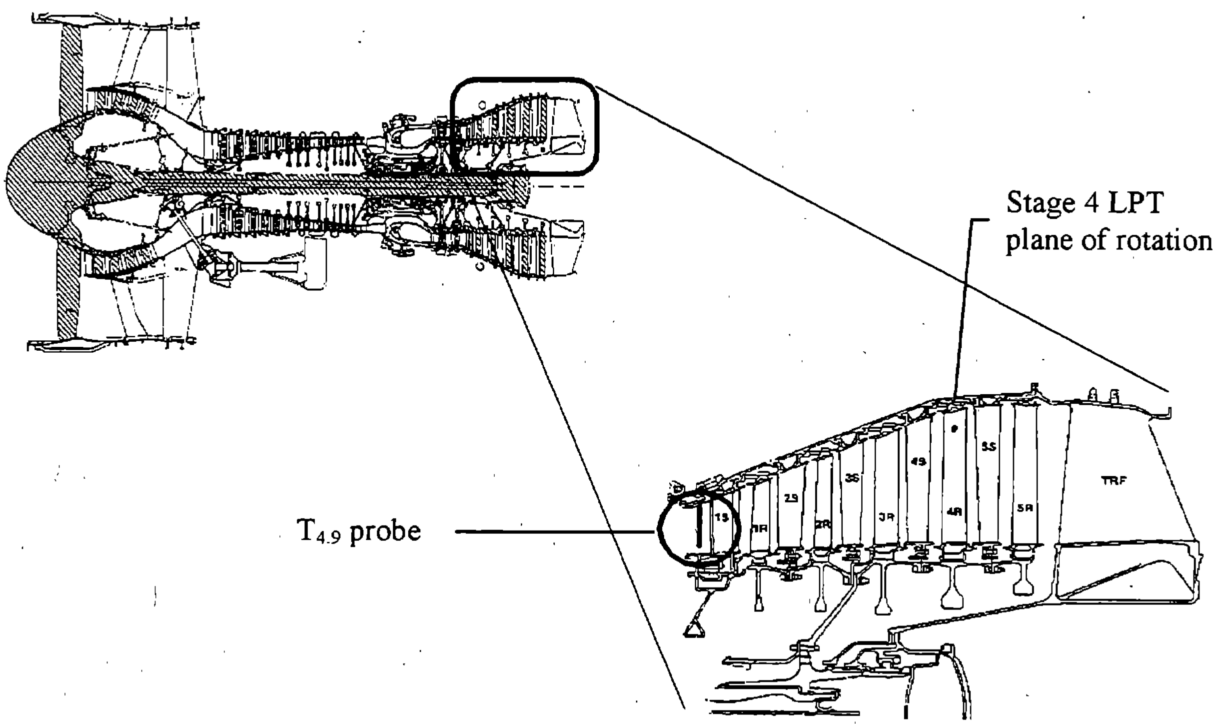


Figure 2. Cross section of CF6-80C2 engine and expanded view of LPT module

The Safety Board is aware of a similar event that occurred on September 5, 1997, when a Federal Express (FedEx) McDonnell Douglas MD-11 airplane, equipped with GE CF6-80C2 engines, had an uncontained LPT failure in the plane of the stage 4 LPT rotor. The disassembly of the FedEx engine showed that a stage 1 LPT airseal segment had broken loose from the LPT case and passed through the gaspath causing the breakage of the downstream turbine blades. As in the American Airlines LPT, the damage in the FedEx LPT rotor was more extensive downstream along the gaspath. The evidence shows that both the American Airlines and FedEx LPT cases withstood the initial containment challenge of the separation of an LPT blade; however, neither case could withstand the loads imparted by the resultant mass of broken LPT airfoils. This suggests that the design containment capability of the LPT case is inadequate.

To gain a clearer understanding of the number and frequency of uncontained LPT failures in CF6 engines, the Safety Board requested, and GE provided, a list of all such failures that have occurred in the CF6-50 and -80 series commercial engine fleet. The GE data show that the CF6-50 engine had experienced 25 uncontained LPT failures as of 1997, including the PIA and Continental Airlines FMS fracture events, and that the CF6-80C2 engine had experienced 6 uncontained LPT failures as of 1997, including the American Airlines and FedEx events. GE attributed these uncontained LPT failures to LPT blade fractures, FMS fractures, and other causes.

Turbine engine rotor cases are required to ensure containment of fractured blades by 14 CFR 33.19, which states in part that "the design of the compressor and turbine rotor cases must provide for the containment of damage from rotor blade failure." The requirements for turbine containment are further addressed in 14 CFR 33.75, which notes in part that "any probable single or multiple failure...will not cause an engine to...burst (release hazardous fragments through the engine case)." Because the uncontained LPT failures in the CF6-50 and -80C2 engines were attributed to a number of different causes, the LPT containment capability of these engines must be improved to comply with 14 CFR 33.19 and 33.75.

The Safety Board notes that as a result of uncontained LPT failures that were initiated by blade or shaft fractures in the Pratt & Whitney (P&W) JT8D-1 through -17AR and JT9D engines, the FAA required modification of those engines to improve the LPT containment through Airworthiness Directives 97-19-14 and 96-25-10, respectively.[17] The same standard should apply to GE CF6 engines. Therefore, the Safety Board believes that the FAA should require GE to improve the ability of the CF6-50 and the CF6-80 series engines to prevent fractured LPT blades from being liberated through the engine cowling.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require General Electric Aircraft Engines to modify the CF6-50 engine to eliminate the impediments to the aft translation of the low pressure turbine rotor that limits the amount of meshing that occurs in the event of a fan midshaft fracture. (A-98-125)
>
> Require General Electric Aircraft Engines to improve the ability of the CF6-50 and the CF6-80 series engines to prevent fractured low pressure turbine blades from being liberated through the engine cowling. (A-98-126)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

Jim Hall

By: Jim Hall
Chairman

Enclosure

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[17] The CF6-50 series engine, which was first certificated in 1972 and has about 2,008 engines in service, experienced 25 uncontained LPT failures. The CF6-80 series engine, which was first certificated in 1981 and has about 2,977 engines in revenue service, experienced 6 uncontained LPT failures. In comparison, the JT8D-1 through -17AR engine series, which was first certificated in 1961 and has about 9,975 engines in service, experienced about 55 uncontained LPT failures. The JT9D engine, which was first certificated in 1968 and has about 566 engines in service, experienced 64 uncontained LPT failures. All of the uncontained LPT failures in the GE CF6-50 and -80 series engines and in the P&W JT8D and JT9D engines were blade penetrations caused by fractures of the LPT blades or the fracture of the LPT turbine drive shaft.

National Transportation Safety Board
Washington, D.C. 20594

Brief of Incident

Adopted 07/31/98

NYC96IA036
FILE NO. 6000 12/06/95 JAMAICA,NY AIRCRAFT REG NO. APBAK TIME (LOCAL)- 21:50 EST

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MAKE/MODEL -Boeing-747-240
ENGINE MAKE/MODEL -G E CF6-50E2
AIRCRAFT DAMAGE -Minor
NUMBER OF ENGINES -4
OPERATING CERTIFICATES -NONE
NAME OF CARRIER -PAKISTAN INTERNATIONAL AIRLINE
TYPE OF FLIGHT OPERATION -Scheduled
-International
-Passenger/cargo
REGULATION FLIGHT CONDUCTED UNDER -14 CFR 129

| | FATAL | SERIOUS | MINOR/NONE |
|---|---|---|---|
| CREW | 0 | 0 | 15 |
| PASS | 0 | 0 | 240 |

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LAST DEPARTURE POINT - Same as Incident
DESTINATION - PARIS,FRANCE

AIRPORT PROXIMITY - Off airport/airstrip
AIRPORT NAME - JOHN F KENNEDY INTL
RUNWAY IDENTIFICATION - Unk/Nr
RUNWAY LENGTH/WIDTH (Feet) - Unk/Nr
RUNWAY SURFACE - Unk/Nr
RUNWAY SURFACE CONDITION - Unk/Nr

CONDITION OF LIGHT - Night (dark)

WEATHER INFO SOURCE- Weather observation facility

BASIC WEATHER - Visual (VMC)
LOWEST CEILING - 2500 FT Overcast
VISIBILITY - 20.000 SM
WIND DIR/SPEED - 260 /007 KTS
TEMPERATURE (F) - 39
OBSTR TO VISION - None
PRECIPITATION - None

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PILOT-IN-COMMAND AGE - 59

CERTIFICATES/RATINGS
Airline transport
Multiengine land
INSTRUMENT RATINGS
Airplane

FLIGHT TIME (Hours)

TOTAL ALL AIRCRAFT - 15000
LAST 90 DAYS - 50
TOTAL MAKE/MODEL - 4000
TOTAL INSTRUMENT TIME - Unk/Nr

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After takeoff, about 1,000 ft agl, the crew of the Boeing 747-240 heard a "thudding noise," followed by a loss of power in the number two engine. An engine shut down was completed, and an uneventful landing was made at the departure airport. The airplane was equipped with General Electric CF6-50E2 engines. Examination revealed that the low pressure turbine module, which included a portion of the fan mid shaft (FMS) and turbine rear frame, was missing. The airplane sustained damage to the left wing leading and tailing edge flaps, the left main wing landing gear doors, and the number one engine. Examination of the number two engine revealed a fracture face on the forward end of the FMS that showed multiple fatigue origins and circumferential cracks. There were also areas on the FMS that were heat affected. The FMS had previously been installed in a CF6-50 engine that had sustained a failure of the number 3 bearing inner race. The engine had been inspected by company personnel, and records did not reflect that they inspected the FMS for heat affected material. Fatigue cracks located in the heat-affected areas were found to have Sermetel paint and debris in the cracks.

NYC96IA036
FILE NO.6000 12/06/95 JAMAICA,NY AIRCRAFT REG NO. APBAK TIME (LOCAL)- 21:50 EST

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Occurrence# 1 LOSS OF ENGINE POWER(TOTAL) - MECH FAILURE/MALF
Phase of operation TAKEOFF - INITIAL CLIMB

Findings
1. 1 ENGINE
2. TURBINE ASSEMBLY,SHAFT - FATIGUE
3. MAINTENANCE,INSPECTION OF AIRCRAFT - INADEQUATE - COMPANY MAINTENANCE PERSONNEL

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The National Transportation Safety Board determines the probable cause(s) of this incident was:
failure of the number two engine fan mid shaft, due a fatigue fracture caused by a previous bearing failure, and failure of the operator's maintenance personnel to detect the cracks during subsequent inspections.

# National Transportation Safety Board
Washington, D.C. 20594

## Safety Recommendation

**Date:** December 18, 1998

**In reply refer to:** A-98-127 through -128

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On April 18, 1997, at 1824 Pacific daylight time, America West flight 66 (AWE66), a Boeing 737, and Ameriflight 1898 (AMF1898), a Beech 99, were involved in a near-midair collision approximately 25 miles south of McCarran International Airport, Las Vegas, Nevada. A flight attendant in the cabin fell and was seriously injured as AWE66 maneuvered to avoid the Ameriflight aircraft. Both flights were operating in visual meteorological conditions at the time of the accident.[1]

AMF1898 had departed Las Vegas, en route to Burbank, California, as a nonscheduled, domestic cargo flight under 14 Code of Federal Regulations (CFR) Part 135. AWE66 had departed from John Wayne - Orange County Airport as a scheduled passenger flight operating under 14 CFR Part 121. The pilot of AMF1898 had elected to depart Las Vegas on a visual flight rules (VFR) flight plan and to fly at 10,500 feet. A review of the recorded voice communications between the radar controller at the Las Vegas terminal radar approach control (TRACON) and the crews of each airplane indicated that the controller terminated radar services with AMF1898 at the lateral limit of the Las Vegas class B[2] airspace. AWE66 contacted the Las Vegas radar controller about 40 seconds later, about 45 miles southwest of Boulder City at 12,000 feet. The flight was directed to descend to an altitude of 10,000 feet on heading 020. One minute later, the controller issued traffic to the crew of AWE66, "twelve o'clock three miles

[1] In accordance with 49 CFR Part 830.2, the Safety Board classified this event as an aircraft accident because of the serious injury to the flight attendant.
[2] Class B airspace is generally defined as that airspace from the surface to 10,000 feet mean sea level surrounding the nation's busiest airports in terms of airport operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored and consists of a surface area and two or more layers (some Class B airspace areas resemble upside down wedding cakes). An air traffic control (ATC) clearance is required for all aircraft to operate in class B airspace, and all aircraft that are so cleared receive separation services within the airspace.

opposite direction, altitude indicates nine thousand three hundred," and then instructed the crew to "climb as you wish." Twenty seconds later, the controller advised AWE66 that the traffic was no longer a factor. The pilot replied, "That was close."

On initial contact with Las Vegas TRACON, the controller issued AWE66 a descent clearance and vector that placed it in direct conflict with AMF1898. The controller then issued a traffic advisory to AWE66 and authorized a climb, if necessary, to comply with an anticipated traffic alert and collision avoidance system (TCAS) resolution advisory (RA),[3] recognizing that at least one of the two aircraft would need to maneuver to avoid the other. AMF1898 had been receiving radar advisories from the Las Vegas TRACON until less than 2 minutes before the accident. ATC services were terminated at the class B airspace boundary despite an earlier pilot request to continue VFR radar traffic advisory services for the duration of the flight.

After a departing VFR aircraft leaves charted class B airspace, controllers are no longer required to provide radar advisory service. Although fully within the scope of her authority under current rules, the controller's decision to terminate service to AMF1898 immediately after the aircraft exited class B airspace eliminated the possibility of providing either a traffic advisory to the pilot or a suggestion that AMF1898 remain at or below 9,500 feet until passing AWE66. Instead, AWE66 received a late advisory, AMF1898 received no ATC assistance at all, and an accident occurred.

This accident points out an anomaly in the level of service provided to VFR aircraft operating in terminal areas. Air traffic controllers are required to provide advisories to aircraft departing airports located within class B airspace areas only until the aircraft exits class B airspace, which could in some cases result in termination of radar service as soon as 5 to 7 miles after departure. The same aircraft departing an airport located in class C[4] airspace, normally of lower traffic density and complexity than class B, would be entitled to radar advisory service until at least 20 miles after departure because controllers are prohibited from terminating radar service within the class C outer area without pilot request. It seems reasonable that aircraft operating near class B airspace, by definition the most complex terminal airspace in the United States, should receive at least the same level of service as aircraft operating near less complex class C airports. Extending the availability of mandatory advisory services to cover the most likely areas for encounters between VFR aircraft and those operating under IFR would improve

[3] RAs are visual and aural warnings from TCAS that alert pilots to a nearby aircraft presenting a collision threat. RAs direct pilots to pitch the airplane nose-up or nose-down, as required, to resolve the collision threat.

[4] Class C airspace is generally defined as that airspace from the surface to 4,000 feet above the airport elevation surrounding those airports that have an operational control tower, are serviced by a radar approach control, and have a certain number of instrument flight rules (IFR) operations or passenger enplanements. Although the configuration of each class C area is individually tailored, the airspace usually consists of a charted area of 5 nautical mile radius extending from the surface to 4,000 feet above airport elevation, a charted outer circle from 5 to 10 nautical miles radius extending from 1,200 feet to 4,000 feet above airport elevation, and an uncharted outer area generally including the remainder of the airport approach control's airspace to a minimum radius of 20 miles from the airport. Each person must establish and maintain two-way radio communications with the ATC facility providing air traffic services prior to entering the charted class C airspace. Class C services include separation of VFR aircraft from IFR aircraft.

safety by reducing the chance of conflicts, such as the one that precipitated this accident. The Safety Board believes that the Federal Aviation Administration (FAA) should revise Handbook 7110.65, "Air Traffic Control," to require that controllers provide pilots of aircraft departing class B terminal areas under VFR the option of continuing to receive radar advisory services until leaving airspace delegated to the applicable terminal radar approach control facility.

The design of the CRESO 3 standard terminal arrival[5] (STAR) into Las Vegas appears to have contributed to this near-midair collision. Because of the surrounding high terrain, southbound VFR flights departing Las Vegas are concentrated in the location of this accident. The CRESO 3 STAR routing directs air carrier traffic into the same area, descending in a direction opposite to the departing VFR flights. Arrival procedures, such as the CRESO 3, are developed in accordance with FAA Order 7100.9B, "Standard Terminal Arrival (STAR)." This order does not address known concentrations of VFR traffic as a consideration in the selection of STAR routes, except possibly through the interpretation of a general direction that STARs be "compatible with local traffic flow management requirements." However, in light of the known limitations of visual traffic separation, the placement of VFR and IFR traffic flows in close proximity should be minimized in high density areas where conflicts are likely.

As the result of an inquiry from the Safety Board regarding this accident, on October 15, 1997, the manager of the Las Vegas TRACON stated:

> In response to the request for information regarding planned airspace changes that would alleviate the possibility of another incident involving a VFR aircraft climbing in the path of an IFR aircraft on the CRESO arrival, such as the aircraft accident involving AWE66, the changes involved encompass a long-term project, require much more planning and development, and have yet to be instituted.

As of July 1998, the CRESO arrival remains unchanged. The Safety Board would welcome further information on the FAA's progress on the modification of airspace and procedures in the Las Vegas area. The Safety Board believes that the FAA should revise Order 7100.9, "Standard Terminal Arrival (STAR)," to provide a specific instruction to STAR designers to segregate concentrated IFR traffic from concentrated VFR traffic unless no reasonable alternative is available. Further, existing procedures, including the CRESO 3 STAR, should be reviewed to ensure compliance with this requirement and revised if necessary.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Revise Handbook 7110.65, "Air Traffic Control," to require that controllers provide pilots of aircraft departing class B terminal areas under visual flight rules the option of continuing to receive radar advisory services until leaving airspace delegated to the applicable terminal radar approach control facility. (A-98-127)

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[5] A planned air traffic control IFR arrival procedure published for pilot use in graphic and/or textual form. STARs provide transition from the en route structure to an outer fix or an instrument approach fix/arrival waypoint in the terminal area.

Revise Order 7100.9, "Standard Terminal Arrival (STAR)," to provide a specific instruction to STAR designers to segregate concentrated instrument flight rules traffic from concentrated visual flight rules traffic unless no reasonable alternative is available. Further, existing procedures should be reviewed to ensure compliance with this requirement and revised if necessary. (A-98-128)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

Jim Hall

By: Jim Hall
Chairman

# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

**Date:** December 9, 1998

**In reply to refer to:** R-98-69

Mr. Robert Prince
General Manager
Massachusetts Bay Transportation Authority
10 Park Plaza
Boston, Massachusetts 02116

At 3:23 p.m., eastern daylight time, on May 4, 1998, Massachusetts Bay Transportation Authority (MBTA) passenger train 642-43-626-27, consisting of four passenger cars and crewed by a single train operator, derailed its two lead cars as the train proceeded within a 500-foot-radius curve between Government Center and Bowdoin Stations on the MBTA system's Blue Line. Three of the train's 10 passengers and the train operator reported minor injuries.

The National Transportation Safety Board determined that the probable cause of this accident was the failure of the MBTA to have adequate procedures in place to ensure safe operations when restraining rails are not in place.

On the afternoon of May 4, train 642-43-626-27 was in revenue service on the Blue Line, making regularly scheduled stops to pick up and discharge passengers. The train operator said she had departed Government Center Station and was proceeding toward Bowdoin Station at 10 mph in a curve when she heard a loud "bang" and the power went out. Postaccident tests conducted by the MBTA indicated that train 642-43-626-27 had been moving at 10 mph when the derailment occurred.

Investigation revealed that a wheel on the number 2 truck of the second car had climbed the rail and caused the car to derail. The derailment of the second car forced the lead car to derail. The train traveled about 40 feet after derailing and struck the side of the tunnel wall. A wayside telephone on the tunnel wall caught fire after being struck by the derailed equipment.

The train operator and an MBTA inspector evacuated the passengers, moving them along the tracks to the Bowdoin Station platform. The Boston Fire Department responded to the accident scene and extinguished the fire at the wayside telephone. Emergency medical responders at the Bowdoin Station treated the injured passengers and the train operator. The train operator and two passengers were transported by ambulance to Massachusetts General Hospital. The passengers were treated for smoke inhalation and released later that day. The train operator was treated for smoke inhalation and dizziness and then released. The carrier's postaccident toxicological test of the train operator for the presence of drugs and alcohol was negative.

To carry out an established renewal plan, the MBTA Right-of-Way Department had been replacing 39-foot sections of the rail and track structure each night. The night before the accident, the MBTA Right-of-Way Department had been working on and had replaced a portion of the rail and track structure in the curve where the accident occurred. The running rails, restraining rail, and all the ballast, ties, plates, and spikes were removed; and new ballast, ties, running rails, plates, and spikes were installed. The new restraining rail, however, was not installed before the track was put back in service for the morning rush on the day of the accident.

A restraining rail is used both to prevent derailments and to reduce rail wear. The restraining rail is positioned next to the inside running rail. When a car negotiates a curve, centrifugal force causes the wheel set to move toward the outside rail. Contact between the inside wheel and the restraining rail prevents the wheel set from pushing against the outside rail, which prevents wheel climb and subsequent derailment.

In response to the removal of the restraining rail, the MBTA Right-of-Way Department established a 10-mph speed limit on this section of track. The speed limitation was communicated to the train operator by a flashing yellow lantern located to the right of the rail. However, this particular curved section of track already had a speed limit of 10 mph, even when the restraining rail was in place. Therefore, the speed limit imposed by the MBTA Right-of-Way Department had no effect on safe operations.

The investigation determined that the MBTA does not have a policy addressing safe train operations over track where restraining rails are required but are not in place. Consequently, the Safety Board concluded that a similar accident could occur again when restraining rails are removed for maintenance or repair.

Therefore, the National Transportation Safety Board makes the following safety recommendation to the Massachusetts Bay Transportation Authority:

> Formulate and implement a policy that will provide for the safe movement of trains on tracks that require restraining rails when those track appliances are not in place. (R-98-69)

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation R-98-69 in your reply. If you need additional information, you may call (202) 314-6431.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman

# National Transportation Safety Board

Washington, D.C. 20594

**Safety Recommendation**

**Date:** December 9, 1998

**In reply refer to:** R-98-70

Mr. Carl T. Johnson
President
Compressed Gas Association, Inc.
1725 Jefferson Davis Highway
Suite 1004
Arlington, Virginia 22202-4102

About 12:00 p.m., central standard time, on November 22, 1997, a frost ring that signified product leakage was discovered on the bottom center of tank car TEAX 3417 at the Georgia Gulf Corporation chemical plant in Pasadena, Texas. When the plant's employees discovered the leak, they were weighing the tank car, which contained 140,377 pounds (29,054 gallons) of a propylene/propane mixture, a liquefied flammable gas. The employees successfully offloaded most of the mixture from the tank car to fixed storage tanks. To transfer the residual cargo, they isolated the tank car. By 7:00 a.m. the next morning, November 23, they had transferred the residual to a cargo tank truck.[1]

No injuries or fatalities were reported as a result of the failure of the tank car. Georgia Gulf estimated that approximately 250 pounds (52 gallons) of the cargo were released. Total damage, including the cost of the clean up, loss of product, and repair of the tank car, was estimated to be slightly less than $9,300.

A postaccident examination revealed that the product had been released through a circumferential crack in the bottom center of the tank. A metallurgical examination of the crack surfaces revealed indications of brittle (cleavage) fracture from a single event that had cooled the tank car to less than -50 °F.

About 6 weeks before the accident, the tank car had arrived at the Bayou Railcar Services, Inc., (Bayou) repair shop in Holden, Louisiana, for routine maintenance and testing. At the request of the owner of the tank car, Bayou purged the tank car on October 17 with cryogenic nitrogen gas because of a change in the product to be carried.

[1] For more information, read Hazardous Materials Accident Report--Failure *of Tank Car TEAX 3417 and Subsequent Release of Liquefied Petroleum Gas, Pasadena, Texas, November 22, 1997* (NTSB/HZM-98/01/SUM).

Because Bayou did not use external cryogenic vaporizers and a low-temperature protection device, the tank car was probably injected with cryogenic nitrogen, including entrained liquid nitrogen. The liquefied nitrogen in the cylinder was under an internal pressure between 123 psig and 237 psig and would, therefore, have had a maximum temperature between -256 °F and -274 °F. Consequently, if the liquefied nitrogen had any contact with the tank shell directly below the eduction line, the result would have been the very rapid super cooling of the tank shell in the area of contact to less than -50 °F.

The National Transportation Safety Board determines that the probable cause of the thermal shock failure and the subsequent leakage of product from tank car TEAX 3417 was the failure of Bayou Railcar Services, Inc., to utilize sufficient safeguards to ensure that the nitrogen was properly warmed before it was injected into the tank car during nitrogen purging.

In 1992, the Compressed Gas Association, Inc., (CGA) issued *Recommended Procedures for Nitrogen Purging of Tank Cars* (CGA Pamphlet P-16-1992). The CGA noted that introducing liquid nitrogen into tank cars not specifically designed for cryogenic service can result in tank failure caused by a phenomenon known as thermal shock (very rapid and severe cooling of the tank). To prevent thermal shock, the CGA recommended using cryogenic vaporizers that are external to the nitrogen cylinders to warm the liquid nitrogen to a gas with a temperature of not less than -20 °F before the nitrogen is injected into a tank car. The CGA also recommended using a low-temperature protection device that stops the flow of nitrogen to the tank car if the temperature of the nitrogen falls below -20 °F.

During the Safety Board's investigation of the accident, the CGA was unable to locate any technical information that might have been used in developing its nitrogen purging procedures. Safety Board investigators contacted some of the CGA committee members who had developed the procedures, including those members who represented tank car manufacturers and owners, in an effort to determine how the -20 °F temperature threshold had been derived. The members contacted could not recall whether the threshold was based on any specific testing or engineering analysis. They indicated that the threshold had most probably been recommended by tank car experts who were drawing on their collective experience and that the committee had, therefore, adopted the recommendation. All the committee members contacted stated they were no longer able to locate any meeting notes that would verify their accounts of how the threshold had been determined. The minimum injection temperature of -20 °F specified in the CGA standard has not been verified through scientific tests or engineering analysis.

Based on the definition of the ductile-to-brittle transition temperature as the temperature at which 50 percent of a fracture exhibits shear features and 50 percent exhibits cleavage features, the transition temperature for the TC-128 steel in tank car TEAX 3417 would be about -5 °F. Because TC-128 steel has been the most commonly used grade of steel in the construction of tank cars over the past 20 or more years, the likelihood is strong that the steel found throughout the tank car fleet will have comparable ductile-to-brittle transition temperatures. The Safety Board is concerned that other grades of tank car steels may also have high transition temperatures. Consequently, because the CGA's minimum injection temperature is not supported by an engineering evaluation and because grades of steel used in tank cars have high ductile-to-

brittle transition temperatures, the Safety Board concludes that the current CGA procedures for nitrogen purging of railroad tank cars do not adequately protect the tank cars from brittle failure.

Therefore, the Safety Board believes that the CGA, with the assistance of the Federal Railroad Administration and the Association of American Railroads, should revise the CGA's *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels.

Therefore, the National Transportation Safety Board issues the following safety recommendation to the Compressed Gas Association, Inc.:

> In cooperation with the Association of American Railroads and the Federal Railroad Administration, revise its *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels. (R-98-70)

Also, the Safety Board issued Safety Recommendations R-98-71 to the Federal Railroad Administration and R-98-72 to the Association of American Railroads.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation R-98-70 in your reply. If you need additional information, you may call (202) 314-6460.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in this recommendation.

By: Jim Hall
Chairman

# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

**Date:** December 9, 1998

**In reply refer to:** R-98-71

Honorable Jolene M. Molitoris
Administrator
Federal Railroad Administration
400 7th Street, S.W.
Washington, D.C. 20590

About 12:00 p.m., central standard time, on November 22, 1997, a frost ring that signified product leakage was discovered on the bottom center of tank car TEAX 3417 at the Georgia Gulf Corporation chemical plant in Pasadena, Texas. When the plant's employees discovered the leak, they were weighing the tank car, which contained 140,377 pounds (29,054 gallons) of a propylene/propane mixture, a liquefied flammable gas. The employees successfully offloaded most of the mixture from the tank car to fixed storage tanks. To transfer the residual cargo, they isolated the tank car. By 7:00 a.m. the next morning, November 23, they had transferred the residual to a cargo tank truck.[1]

No injuries or fatalities were reported as a result of the failure of the tank car. Georgia Gulf estimated that approximately 250 pounds (52 gallons) of the cargo were released. Total damage, including the cost of the clean up, loss of product, and repair of the tank car, was estimated to be slightly less than $9,300.

A postaccident examination revealed that the product had been released through a circumferential crack in the bottom center of the tank. A metallurgical examination of the crack surfaces revealed indications of brittle (cleavage) fracture from a single event that had cooled the tank car to less than -50 °F.

About 6 weeks before the accident, the tank car had arrived at the Bayou Railcar Services, Inc., (Bayou) repair shop in Holden, Louisiana, for routine maintenance and testing. At the request of the owner of the tank car, Bayou purged the tank car on October 17 with cryogenic nitrogen gas because of a change in the product to be carried.

[1] For more information, read Hazardous Materials Accident Report--Failure *of Tank Car TEAX 3417 and Subsequent Release of Liquefied Petroleum Gas, Pasadena, Texas, November 22, 1997* (NTSB/HZM-98/01/SUM).

Because Bayou did not use external cryogenic vaporizers and a low-temperature protection device, the tank car was probably injected with cryogenic nitrogen, including entrained liquid nitrogen. The liquefied nitrogen in the cylinder was under an internal pressure between 123 psig and 237 psig and would, therefore, have had a maximum temperature between -256 °F and -274 °F. Consequently, if the liquefied nitrogen had any contact with the tank shell directly below the eduction line, the result would have been the very rapid super cooling of the tank shell in the area of contact to less than -50 °F.

The National Transportation Safety Board determines that the probable cause of the thermal shock failure and the subsequent leakage of product from tank car TEAX 3417 was the failure of Bayou Railcar Services, Inc., to utilize sufficient safeguards to ensure that the nitrogen was properly warmed before it was injected into the tank car during nitrogen purging.

In 1992, the Compressed Gas Association, Inc., (CGA) issued *Recommended Procedures for Nitrogen Purging of Tank Cars* (CGA Pamphlet P-16-1992). The CGA noted that introducing liquid nitrogen into tank cars not specifically designed for cryogenic service can result in tank failure caused by a phenomenon known as thermal shock (very rapid and severe cooling of the tank). To prevent thermal shock, the CGA recommended using cryogenic vaporizers that are external to the nitrogen cylinders to warm the liquid nitrogen to a gas with a temperature of not less than -20 °F before the nitrogen is injected into a tank car. The CGA also recommended using a low-temperature protection device that stops the flow of nitrogen to the tank car if the temperature of the nitrogen falls below -20 °F.

During the Safety Board's investigation of the accident, the CGA was unable to locate any technical information that might have been used in developing its nitrogen purging procedures. Safety Board investigators contacted some of the CGA committee members who had developed the procedures, including those members who represented tank car manufacturers and owners, in an effort to determine how the -20 °F temperature threshold had been derived. The members contacted could not recall whether the threshold was based on any specific testing or engineering analysis. They indicated that the threshold had most probably been recommended by tank car experts who were drawing on their collective experience and that the committee had, therefore, adopted the recommendation. All the committee members contacted stated they were no longer able to locate any meeting notes that would verify their accounts of how the threshold had been determined. The minimum injection temperature of -20 °F specified in the CGA standard has not been verified through scientific tests or engineering analysis.

Based on the definition of the ductile-to-brittle transition temperature as the temperature at which 50 percent of a fracture exhibits shear features and 50 percent exhibits cleavage features, the transition temperature for the TC-128 steel in tank car TEAX 3417 would be about -5 °F. Because TC-128 steel has been the most commonly used grade of steel in the construction of tank cars over the past 20 or more years, the likelihood is strong that the steel found throughout the tank car fleet will have comparable ductile-to-brittle transition temperatures. The Safety Board is concerned that other grades of tank car steels may also have high transition temperatures. Consequently, because the CGA's minimum injection temperature is not supported by an engineering evaluation and because grades of steel used in tank cars have high ductile-to-

brittle transition temperatures, the Safety Board concludes that the current CGA procedures for nitrogen purging of railroad tank cars do not adequately protect the tank cars from brittle failure.

Therefore, the Safety Board believes that the CGA, with the assistance of the Federal Railroad Administration and the Association of American Railroads, should revise the CGA's *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels.

Therefore, the National Transportation Safety Board issues the following safety recommendation to the Federal Railroad Administration:

> Cooperate with the Compressed Gas Association, Inc., in its efforts to revise its *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels. (R-98-71)

Also, the Safety Board issued Safety Recommendations R-98-70 to the Compressed Gas Association, Inc., and R-98-72 to the Association of American Railroads.

Please refer to Safety Recommendation R-98-71 in your reply. If you need additional information, you may call (202) 314-6460.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in this recommendation.

By: Jim Hall
Chairman

# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

**Date:** December 9, 1998

**In reply refer to:** R-98-72

Mr. Edward R. Hamberger
President
Association of American Railroads
50 F Street, N.W.
12th Floor
Washington, D.C. 20001

About 12:00 p.m., central standard time, on November 22, 1997, a frost ring that signified product leakage was discovered on the bottom center of tank car TEAX 3417 at the Georgia Gulf Corporation chemical plant in Pasadena, Texas. When the plant's employees discovered the leak, they were weighing the tank car, which contained 140,377 pounds (29,054 gallons) of a propylene/propane mixture, a liquefied flammable gas. The employees successfully offloaded most of the mixture from the tank car to fixed storage tanks. To transfer the residual cargo, they isolated the tank car. By 7:00 a.m. the next morning, November 23, they had transferred the residual to a cargo tank truck. [1]

No injuries or fatalities were reported as a result of the failure of the tank car. Georgia Gulf estimated that approximately 250 pounds (52 gallons) of the cargo were released. Total damage, including the cost of the clean up, loss of product, and repair of the tank car, was estimated to be slightly less than $9,300.

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The National Transportation Safety Board determines that the probable cause of the thermal shock failure and the subsequent leakage of product from tank car TEAX 3417 was the failure of Bayou Railcar Services, Inc., to utilize sufficient safeguards to ensure that the nitrogen was properly warmed before it was injected into the tank car during nitrogen purging.

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brittle transition temperatures, the Safety Board concludes that the current CGA procedures for nitrogen purging of railroad tank cars do not adequately protect the tank cars from brittle failure.

Therefore, the Safety Board believes that the CGA, with the assistance of the Federal Railroad Administration and the Association of American Railroads, should revise the CGA's *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels.

Therefore, the National Transportation Safety Board issues the following safety recommendation to the Association of American Railroads:

> Cooperate with the Compressed Gas Association, Inc., in its efforts to revise its *Recommended Procedures for Nitrogen Purging of Tank Cars* to specify a minimum threshold temperature for nitrogen that is based on an engineering analysis of ductile-to-brittle transition temperatures of tank car steels. (R-98-72)

Also, the Safety Board issued Safety Recommendations R-98-70 to the Compressed Gas Association, Inc., and R-98-71 to the Federal Railroad Administration.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation R-98-72 in your reply. If you need additional information, you may call (202) 314-6460.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in this recommendation.

By: Jim Hall
Chairman